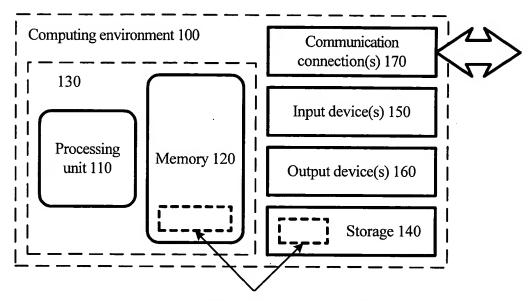
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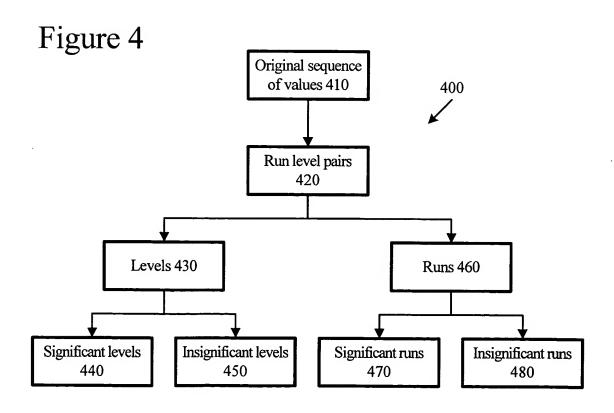
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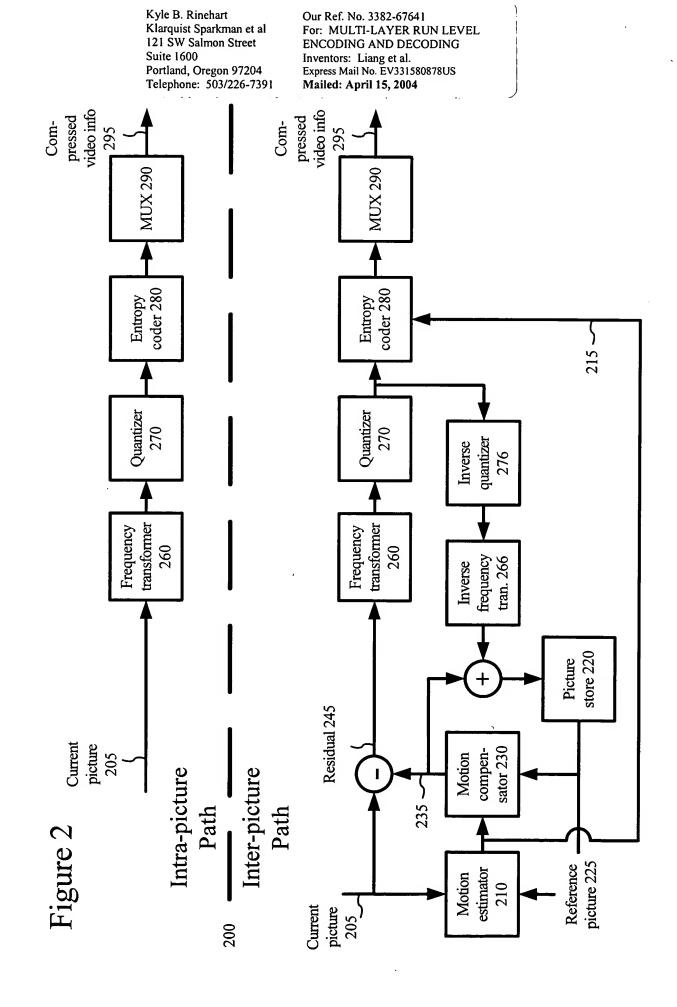
Inventors: Liang et al.

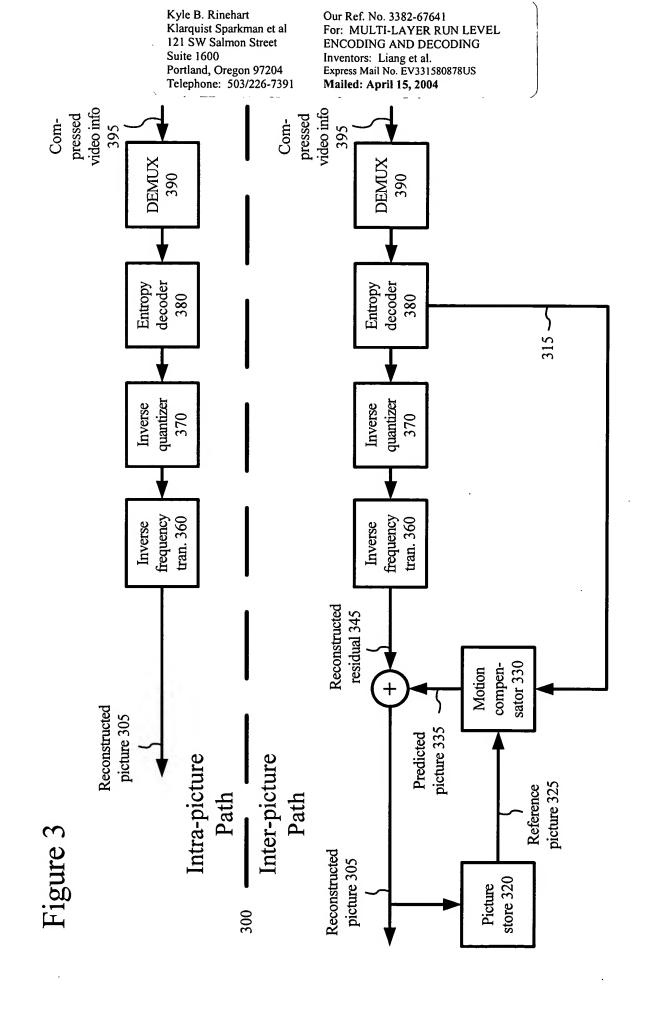
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Software 180 implementing multi-layer run level encoding and/or decoding







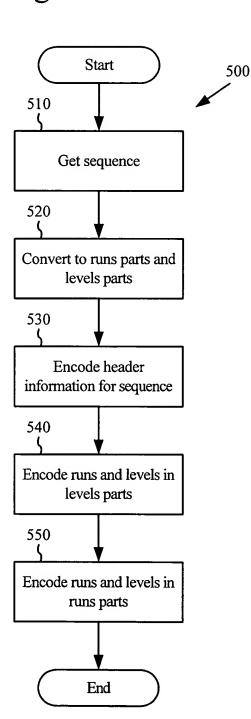
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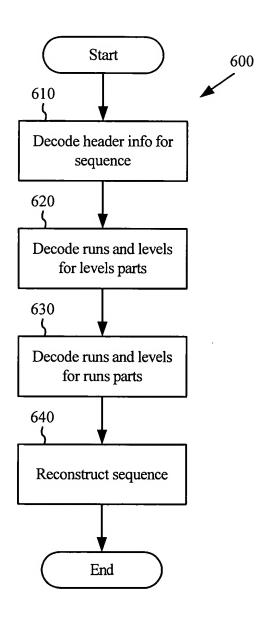
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Figure 5





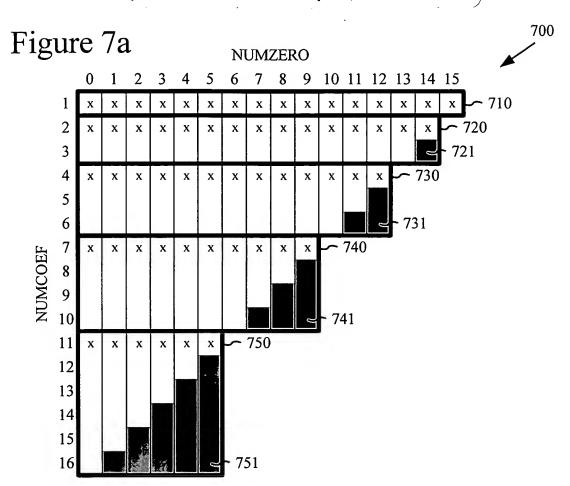
Portland, Oregon 97204

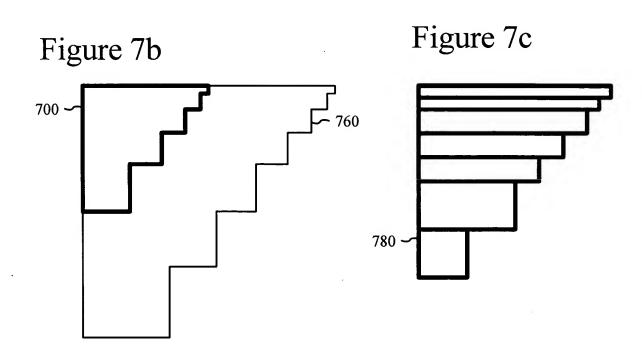
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Size

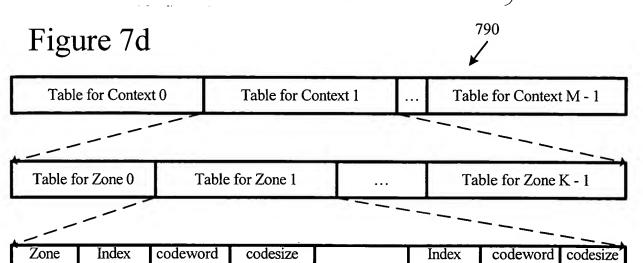
0

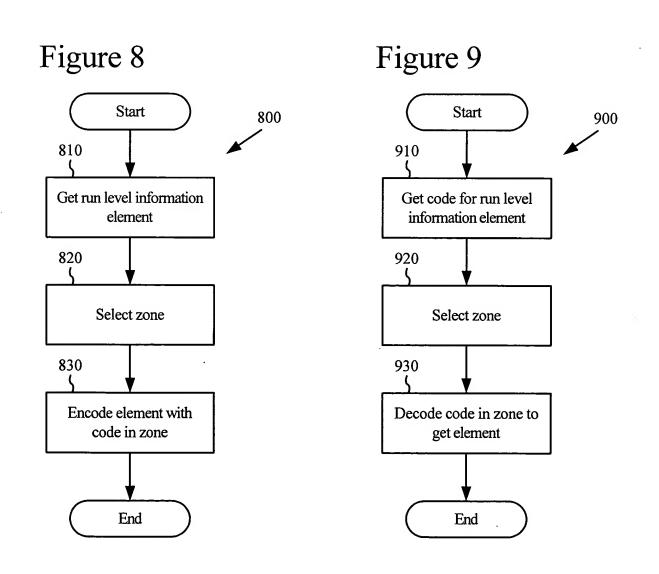
0

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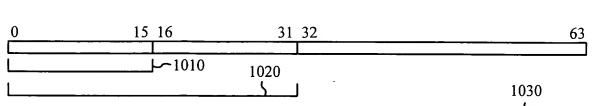


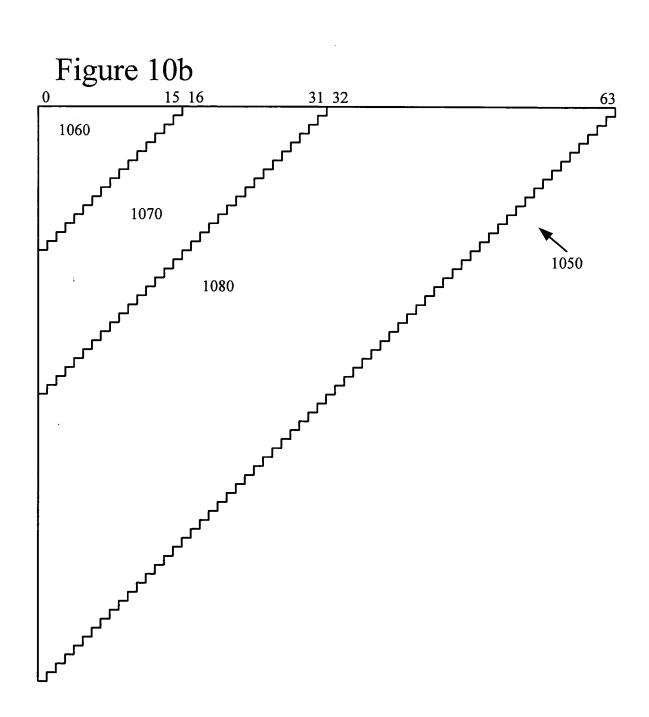
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Figure 10a





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Figure 11a

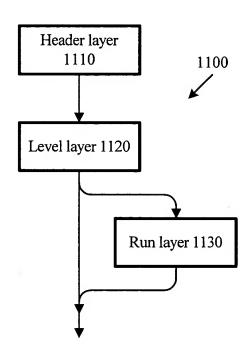


Figure 11d

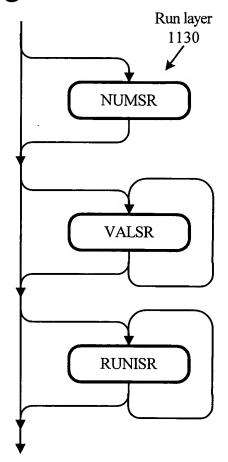
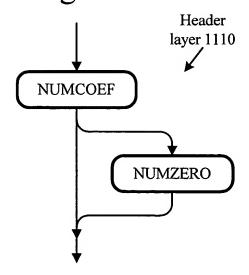


Figure 11b



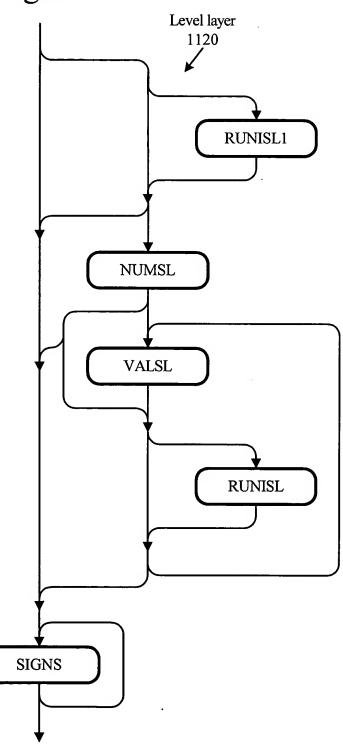
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Figure 11c



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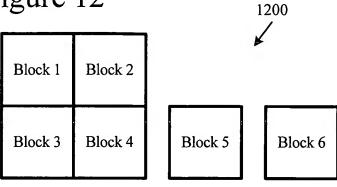
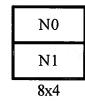
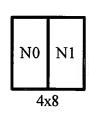


Figure 13a







1310

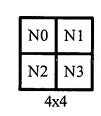


Figure 13b



Current	Neighbor in	Neighbor in	Neighbor in	Neighbor in
block	8x8 mode	8x4 mode	4x8 mode	4x4 mode
8x8	N0	N0 + N1	N0 + N1	N0+N1+N2+N3
8x4 top	(N0+1)/2	N1	(N0+N1+1)/2	N2 + N3
8x4 bottom	Impossible	N0	Impossible	Impossible
4x8 left	(N0+1)/2	(N0+N1+1)/2	N0	N0 + N2
4x8 right	(N0+1)/2	(N0+N1+1)/2	N1	N1 + N3
4x4 No. 0	(N0+2)/4	(N1+1)/2	(N0+1)/2	N2
4x4 No. 1	(N0+2)/4	(N1+1)/2	(N1+1)/2	N3
4x4 No. 2	Impossible	Impossible	Impossible	N0
4x4 No. 3	Impossible	Impossible	Impossible	N1

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Figure 13c



Current Sub-block	Neighbor in 8x8 mode	Neighbor in 8x4 mode	Neighbor in 4x8 mode	Neighbor in 4x4 mode
8x8	N0	N0 + N1	N0 + N1	N0+N1+N2+N3
8x4 top	(N0+1)/2	N0	(N0+N1+1)/2	N0+N1
8x4 bottom	(N0+1)/2	N1	(N0+N1+1)/2	N2+N3
4x8 left	(N0+1)/2	(N0+N1+1)/2	N1	N1+N3
4x8 right	Impossible	Impossible	N0	Impossible
4x4 No. 0	(N0 + 2) / 4	(N0+1)/2	(N1+1)/2	N1
4x4 No. 1	Impossible	Impossible	Impossible	N0
4x4 No. 2	(N0 + 2) / 4	(N1+1)/2	(N1+1)/2	N3
4x4 No. 3	Impossible	Impossible	Impossible	N2

Figure 14a



Block	Context 0	Context 1	Context 2	Context 3	Context 4	Context 5
Mode	Threshold	Threshold	Threshold	Threshold	Threshold	Threshold
8x8	1	3	5	7	16	64
8x4/4x8	1	3	5	7	12	32
4x4	1	3	5	7	16	
Intra	2	6	12	24	63	

Figure 14b



Context = 0;

While (Context \leq MaxContext[BlkMode] - 1 &&

PredNumCoef > ContextThresholds_NUMCOEF[BlkMode][Context])

{ Context ++; }

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Figure 15



Block	Context 0	Context 1	Context 2	Context 3
Mode	Threshold	Threshold	Threshold	Threshold
8x8	1	4	12	64
8x4/4x8	1	4	8	32
4x4	1	3	6	16
Intra	6	18	63	

Figure 16a



```
PredNumCoef = GetPredNumCoef();

Context = GetContext_NUMCOEF(PredNumCoef);

Index = vlc_decode(HufPtr_NUMCOEF[BlkMode][Context]);

if (Index <= 3) {

    NUMCOEF = Index + 1;

    ISLONLY = TRUE; // the absolute values of all nonzero coefficients are equal to 1.
} else {

    ISLONLY = FALSE;

    if ((BlockMode is not 4x4) && (Index == 4 + BlockSize / 2) ) {

        // the last symbol in each context is escape symbol

        EscBits = (BlockMode == 8x8) ? 5 : 4;

        EscIndex = get_bits (EscBits);

        NUMCOEF = EscIndex + BlockSize / 2 + 1; }

    else { NUMCOEF = Index - 3; }
}
```

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Figure 16b



1700

```
PredNumCoef = GetPredNumCoef();
Context = GetContext_NUMCOEF_Intra (PredNumCoef);
Index = vlc_decode (HufPtr NUMCOEF Intra[Context] );
if (Index \leq 3) {
   NUMCOEF = Index + 1;
   ISLONLY = TRUE;
} else {
   ISLONLY = FALSE;
   if (Index = 35) {
         NUMCOEF = 32 + get bits(5);
   } else { NUMCOEF = Index -3; }
}
```

```
PredNumCoef = GetPredNumCoef();
Context = GetContext_NUMCOEF (PredNumCoef);
Index = vlc_decode (HufPtr_NUMCOEF[BlkMode][Context] );
if (Index >= BlockSize) {
  NUMCOEF = Index + 1 - BlockSize;
  ISLONLY = TRUE;
} else {
  NUMCOEF = Index + 1;
  ISLONLY = FALSE;
};
```

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Figure 18

Block	Context 0	Context 1
Mode	Threshold	Threshold
8x8	16	64
8x4/4x8	8	32
4x4	4	16

1800

Figure 19

Block Mode	Context 1 Threshold	Context 2 Threshold	Context 3 Threshold
8x8	6	16	64
8x4/4x8	4	12	32
4x4	4	8	16

2000

Figure 20a

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Block	Number of	
Mode	Zones	
8x8	8	
8x4/4x8	7	
4x4	7	
Intra 8x8	8	

Figure 20b

2010

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Figure 21a



Block	Number of	
Mode	Zones	
8x8	8	
8x4/4x8	10	
4x4	15	
Intra 8x8	8	

Figure 21b



```
ZoneHeight_Inter_8x8[3][8] = {

// 3 contexts, each has 8 zones

{1, 1, 1, 1, 4, 8, 16, 31},

{1, 1, 1, 1, 4, 8, 16, 31},

{1, 1, 1, 1, 4, 8, 16, 31},

};

ZoneHeight_Inter_8x4_and_4x8[3][10] = {

{1, 1, 1, 1, 1, 1, 1, 1, 8, 15},

{1, 1, 1, 1, 1, 1, 1, 4, 5, 15},

{1, 1, 1, 1, 1, 1, 2, 4, 4, 15},

};

ZoneHeight_Intra_8x8[8] =

{1, 1, 2, 2, 4, 8, 16, 28};
```

2200

Figure 22a

```
NUMZERO_EscThresholdLeft[2][8] = {
{0, 0, 0, 0, 8, 16, 16}, // context 0
{0, 0, 12,12, 20, 20, 16, 16}, // context 1
};

NUMZERO_EscThresholdRight[2][8] = {
{32, 32, 32, 32, 32, 40, 48, 44}, // context 0
{32, 32, 44, 44, 52, 52, 48, 40}, // context 1
};

NUMZERO_EscThresholdLeft_Intra[8] = {0, 0, 0, 0, 0, 4, 12, 16};

NUMZERO_EscThresholdRight Intra[8] = {32, 32, 32, 32, 32, 36, 44, 43};
```

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Figure 22b

```
PredNumZero = GetPredNumZero();
Context = GetContext NUMZERO(PredNumZero);
Zone = GetZone_NUMZERO(NUMCOEF);
ZoneHead = GetZoneHead NUMZERO(NUMCOEF);
RightShift = NUMCOEF - ZoneHead;
index = vlc_decode (HufPtr_NUMZERO[BlkMode][Context][Zone]);
if (block mode is not 8x8) {
    NUMZERO = index - RightShift;
} else {
    // check escape symbol
    if (index > 0) {
         NUMZERO = index - 1 +
                NUMZERO_EscThresholdLeft[Context][Zone] - RightShift;
    } else {
         EscIndex = get bits (5);
         if (EscIndex < NUMZERO_EscThresholdLeft[Context][Zone]) {
            // left margin
            NUMZERO = EscIndex - RightShift;
          } else {
             // right margin
             NUMZERO = EscIndex -
                NUMZERO EscThresholdLeft[Context][Zone] +
                NUMZERO_EscThresholdRight[Context][Zone] - RightShift;
         }
}
```

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Figure 22c

```
2220
_/
```

2300

```
PredNumZero = GetPredNumZero();

Context = 0;
If (BlkMode == INTER) {
    Context = GetContext_NUMZERO(PredNumZero);
}

Zone = GetZone_NUMZERO(NUMCOEF);

NUMZERO = vlc_decode (HufPtr_NUMZERO[BlkMode][Context][Zone]);
```

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Figure 24

```
RUNISL1 = Decode_RUNISL1();
if (NUMCOEF - RUNISL1 > 0) {
   //Function returns NUMSL and SingleTwoFound.
    Decode NUMSL(&NUMSL, &SingleTwoFound);
   ISLLeft = NUMCOEF - RUNISL1 - NUMSL;
   if (SingleTwoFound == FALSE) {
        LevelZone = 0;
        LevelThreshold[BlkMode] = IniLevelThreshold[BlkMode];
        ShiftLevel = (NUMSL == 1);
       for (n = NUMSL - 1; n \ge 0; n--) {
           VALSL(n) = Decode VALSL();
           if (n > 0 \&\& ISLLeft) {
                   RUNISL(n) = Decode RUNISL();
                   ISLLeft = ISLLeft - RUNISL(n);
       }
    }
Decode_Signs();
```

Figure 25a

NUMCOEF	RUNISL1=0	RUNISL1 = 1		RUNISL1 = 3
2	0	1		
3	10	0	11	
4	00	01	10	11

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2510

```
Figure 25b
```

}

```
If (ISLONLY == TRUE) {
    RUNISL1 = NUMCOEF;
} else {
   If (NUMCOEF == 1) {
       RUNISL1 = 0;
    } else {
       If (NUMCOEF <= 4) {
              RUNISL1 = Vlc_decode ( HufPtr_RUNISL1_1[NUMCOEF - 2] );
       } else {
              Zone = GetZone_RUNISL1( NUMCOEF);
              index = vlc_decode ( HufPtr_RUNISL1_2 [Zone]);
             if (Zone > 6 && index == 15) {
                    RUNISL1= 15 + get_bits(6);
               } else {
                     RUNISL1= index;
     }
```

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Figure 25c

}

```
If (ISLONLY == TRUE) {
   RUNISL1 = NUMCOEF;
} else {
   If (NUMCOEF == 1) {
       RUNISL1 = 0;
    } else {
       If (NUMCOEF <= 4) {
           RUNISL1 = Vlc_decode(HufPtr_RUNISL1_1[NUMCOEF - 2]);
       } else {
           Zone = GetZone_RUNISL1 Intra(NUMCOEF);
           index = Vlc_decode(HufPtr_RUNISL1_2_Intra[Zone]);
           if (index < 33) {
               RUNISL1 = index;
           } else {
               RUNISL1 = 33 + get_bits(5);
       }
   }
```

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2600

2610

```
Figure 26a
```

```
Figure 26b
```

Figure 26c

NUMCOEF	RUNISL1=0	RUNISL1 = 1	RUNISL1 = 2	RUNISL1 = 3
2	0	1		
3	10	0	11	
4	00	01	10	11

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Figure 26d

NUMCOEF	RUNISL1=0	RUNISL1 = 1	RUNISL1 = 2	
2	0	1		
3	10	11	0	
4	00	01	10	11

Figure27a

	Block	Context 0	Context 1	Context 2
	Mode	Threshold	Threshold	Threshold
I	8x8	10	30	64
	8x4/4x8	4	16	32
	4x4	4	9	16

Figure 27b

2710

```
ZoneHeight_NUMSL[3][8] =
  \{1, 1, 1, 1, 1, 1, 1, 57\},\
  \{1, 1, 1, 1, 2, 4, 8, 46\},\
  {4, 4, 2, 2, 4, 4, 8, 36},
};
```

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Figure 27c

```
Context = GetContext_Level(NUMCOEF);
Zone = GetZone_NUMSL(NUMCOEF - RUNISL1);
index = vlc_decode (HufPtr_NUMSL[Context][Zone]);
if (index == 0) {
        SingleTwoFound = TRUE;
        NUMSL = 1;
} else {
        SingleTwoFound = FALSE;
        if (index < 33) {
            NUMSL = index;
        } else {
            NUMSL = 33 + get_bits(5);
        }
}</pre>
```

Figure 27d

```
Zone = GetZone_NUMSL_Intra(NUMCOEF - RUNISL1);
index = vlc_decode (HufPtr_NUMSL_Intra[Zone]);
if (index == 0) {
         NUMSL = 1;
         SingleTwoFound = TRUE;
} else {
         NUMSL = index;
         SingleTwoFound = FALSE;
}
```

2730

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```
index = vlc_decode(HufPtr_VALSL[LevelZone]);
if (index < 30) {
     VALSL = index + 2;
} else {
        EscScale = 1;
        while (!get_bits(1)) {
            EscScale ++;
        }
        VALSL = EscScale * 32 + get_bits(5);
}
if (ShiftLevel == TRUE) {
     VALSL ++;
     ShiftLevel = FALSE;
}
if (VALSL > LevelThreshold[BlkMode] && LevelZone < 3) {
        LevelThreshold[BlkMode] = LevelThreshold[BlkMode] * 2;
        LevelZone = LevelZone + 1;
}</pre>
```

```
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Suite 1600
```

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Figure 29a

```
Zone = GetZone_RUNISL(ISLLeft);
index = vlc_decode(HufPtr_RUNISL[Context][Zone]);
if (ISLLeft >= 32 && index == 32) {
    RUNISL = 32 + get_bits(5);
} else {
    RUNISL = index;
}
```

Figure 29b

```
Zone = GetZone_RUNISL_Intra(ISLLeft);
index = vlc_decode(HufPtr_RUNISL_Intra[Zone]);
if (ISLLeft >= 32 && index == 32) {
    RUNISL = 32 + get_bits(5);
} else {
    RUNISL = index;
}
```

Figure 30

```
if (NUMZERO == 1) {
    NUMSR = 1;
} else {
    NUMSR = Decod_NUMSR();
    Decode_VALSR();
}
ISRLeft = NUMCOEF - NUMSR;
if (ISRLeft) {
    Decode_RUNISR();
}
```

2910

2900

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Figure 31a

3	1	00
K	/	,

Block	Context 0	Context 1	Context 2
Mode	Threshold	Threshold	Threshold
8x8	20	32	64
8x4/4x8	10	16	32
4x4	8	12	16

Figure 31b

3110

Context_NUMSR = GetContext_NUMSR (NUMZERO); MaxNUMSR = min(NUMCOEF, NUMZERO); Zone = GetZone NUMSR(MaxNUMSR); Index = vlc_decode(HufPtr_NUMSR[Context_NUMSR][Zone]); NUMSR = index + 1;

Figure 31c



Context_NUMSR = GetContext_NUMSR_Intra(NUMZERO); MaxNUMSR = min(NUMCOEF, NUMZERO); Zone = GetZone_NUMSR Intra(MaxNUMSR); Index = vlc_decode(HufPtr_NUMSR_Intra[Context_NUMSR][Zone]); NUMSR = index + 1;

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Figure 32a

Block	Context 0	Context 1	Context 2
Mode	Threshold	Threshold	Threshold
8x8	8	20	64
8x4/4x8	6	12	32
4x4	4	10	16

3200

Figure 32b

```
Context VALSR = GetContext_VALSR(NUMCOEF);
SRSumLeft = NUMZERO;
MaxVALSR = SRSumLeft - NUMSR + 1;
for (SRLeft = NUMSR; SRLeft > 0; SRLeft --) {
   if (SRLeft = 1) {
        VALSR[0] = SRSumLeft;
        break;
    } else if (SRLeft == SRSumLeft) {
        // set all remaining SRs to 1.
        break;
    Zone = GetZone_VALSR(MaxVALSR);
   Index = vlc_decode(HufPtr_VALSR[Context_VALSR][Zone]);
   if (MaxVALSR >= 33 \&\& Index == 32) {
        VALSR[SRLeft - 1] = 33 + get bits (5);
    } else {
        VALSR[SRLeft - 1] = Index + 1;
    SRSumLeft = SRSumLeft - VALSR[SRLeft - 1];
   MaxVALSR = MaxVALSR - VALSR[SRLeft - 1] + 1;
}
```

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Figure 33

```
3300
```

```
Context_VALSR = GetContext VALSR(NUMZERO);
MaxVALSR = SRSumLeft - NUMSR + 1;
for (SRLeft = NUMSR; SRLeft > 0; SRLeft--) {
      if (SRLeft = 1) {
            VALSR = SRSumLeft;
            // save VALSR
            break;
      } else if (SRLeft == SRSumLeft) {
            // set all remaining SRs to 1.
            break;
      Zone = GetZone_VALSR(MaxVALSR);
      Index = vlc_decode(HufPtr_VALSR[Context_VALSR][Zone]);
      VALSR = index + 1;
      // save VALSR
      SRSumLeft = SRSumLeft - VALSR;
      MaxVALSR = MaxVALSR - VALSR + 1;
}
```

Figure 34a

Block	Context 0	Context 1	Context 2
Mode	Threshold	Threshold	Threshold
8x8	8	20	63
8x4/4x8	6	12	31
4x4	4	10	15

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3410

3500

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```
Figure 34b
```

```
ISRLeft = NUMCOEF - NUMSR;
if (ISRLeft) {
    Context = getContext_RUNISR(NUMZERO);
    for (n = 0; n < NUMSR && ISRLeft > 0; n ++) {
        Zone = GetZone_RUNISR(ISRLeft);
        Index = vlc_decode(HufPtr_RUNISR[Context][Zone]);
        if (ISRLeft >= 32 && Index == 32) {
            RUNISR[n] = 32 + get_bits(5);
        } else {
            RUNISR[n] = Index;
        }
        ISRLeft = ISRLeft - RUNISR[n];
    }
}
```

```
ISRLeft = NUMCOEF - NUMSR;
if (ISRLeft) {
        Context = getContext_RUNISR(NUMZERO);
        for (n = 0; n < NUMSR && ISRLeft > 0; n ++) {
            Zone = GetZone_RUNISR(ISRLeft);
            RUNISR[n] = vlc_decode(HufPtr_RUNISR[Context][Zone]);
            ISRLeft = ISRLeft - RUNISR[n];
        }
}
```

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Figure 36a

_								
	0	2	3	9	10	21	22	36
	11	4	8	11	20	23	35	37
	5	7	12	19	24	34	38	49
	6	13	18	25	33	39	48	50
	14	16	26	32	40	47	51	58
	15	27	31	41	46	52	57	59
	17	29	42	44	53	55	60	62
	28	30	43	45	54	56	61	63

Normal Intra Block Scan Pattern

Figure 36b

0	1	3	4	10	11	22	23
2	5	9	12	21	24	36	37
6	8	13	20	25	35	38	48
7	14	19	26	34	39	47	49
15	18	27	33	40	46	50	57
16	28	32	41	45	51	56	58
17	30	42	44	52	55	59	62
29	31	43	53	54	60	61	63

Horizontal Intra Block Scan Pattern

Figure 36c

						•	
0	3	8	9	20	21	34	35
11	7	10	19	22	33	36	49
2	11	18	23	32	37	48	50
4	12	17	24	31	38	47	51
5	16	25	30	39	46	52	57
6	15	29	40	45	53	56	58
13	26	28	41	44	55	59	62
14	27	42	43	54	60	61	63

Vertical Intra Block Scan Pattern



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Figure 36d

361	1
/	

0	2	3	9	10	23	24	38
1	4	8	11	22	25	37	39
5	7	12	21	26	36	40	51
6	13	20	27	35	41	50	52
14	19	28	34	42	49	53	60
15	18	33	43	48	54	59	61
16	29	32	44	47	55	58	62
17	30	31	45	46	56	57	63

8x8 Inter Block Scan Pattern for Progressive Content

Figure 36e

3612	
/	
K	

0	2	4	7	10	14	21	27
1_	5	6	11	13	17	24	29
3	9	12	15	18	22	25	30
8	16	19	20	23	26	28	31

8x4 Inter Block Scan Pattern for Progressive Content

3613

Figure 36f

0	1	3	13
2	4	8	17
5	6	11	24
7	10	15	26
9	14	20	28
12	19	23	29
16	21	25	30
18	22	27	31

4x8 Inter Block Scan Pattern for Progressive Content

Figure 36g

0	3	7	11
1	4	8	12
2	6	9	14
5	10	13	15

4x4 Inter Block Scan Pattern for Progressive Content

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Figure	36h
	-

0	2	6	13	17	29	33	38
1	5	12	16	28	32	37	39
3	11	15	27	31	36	40	51
4	14	22	30	35	41	50	52
7	18	23	34	42	49	53	60
8	19	24	43	48	54 .	59	61
9	20	25	44	47	55	58	62
10	21	26	45	46	56	57	63

8x8 Inter Block Scan Pattern for Interlaced Content

Figure 36i

0	4	6	10	13	17	21	27
1	5	9	14	16	18	24	29
2	7	11	15	19	22	25	30
3	8	12	_ 20	23	26	28	31

8x4 Inter Block Scan Pattern for Interlaced Content

3623

Figure 36j

0	1	2	9	
3	5	8	22	
4	7	15	24	
6	14	17	26	
10	16	19	28	
11	18	23	29	
12	20	25	30	
13	21	27	31	

4x8 Inter Block Scan Pattern for Interlaced Content

Figure 36k

0	4	7	11
1	5	9	13
2	6	10	14
3	8	12	15

3624

4x4 Inter Block Scan Pattern for Interlaced Content

3621